WHAT IS CLAIMED IS:

Method of Detecting Phycocyanin Algae or Bacteria from Reflected Light

General Measurement and Correlation/Estimation Method

1.   A method of determining the presence of phycocyanin-pigmented algae or bacteria in water from light reflected therefrom, said method comprising the steps of:

(a)   obtaining a measurement of reflected light from said water, said measurement comprising a measurement of the respective amount of light in at least five frequency ranges: (i) from about 0.45 μm to about 0.52 μm (ii) from about 0.63 μm to about 0.69 μm; (iii) from about 0.76 μm to about 0.90 μm; (iv) from about 1.55 μm to about 1.75 μm and (v) from about 2.08 μm to about 2.35 μm; and

(b)   relating the approximate amount of said phycocyanin in said water to said respective amounts of light by applying an algorithm relating said respective amounts of light in said at least five frequency ranges to the amount of phycocyanin algae or bacteria in said water.

2.   A method according to claim 1 wherein said measurement of the amount of light in said at least five frequency ranges comprises the measurement, respectively, of: (i) LANDSAT TM band 1, (ii) LANDSAT TM band 3, (iii) LANDSAT TM band 4, (iv) LANDSAT TM band 5 and (v) LANDSAT TM band 7.

3.   A method according to claim 2 wherein said algorithm is any algorithm selected from the group consisting of: $X \approx K_1 - K_2 \times (R31) + K_3 \times (R41) - K_4 \times (R43) - K_5 \times (R53) + K_6 \times (R73) - K_7 \times (R74)$ and equivalents wherein:

X is the approximate amount of phycocyanin algae expressed in micrograms per liter;

K_1 is a value in the range of from about 30 to about 60;

K_2 is a value in the range of from about 5 to about 15;

K_3 is a value in the range of from about 20 to about 35;

K_4 is a value in the range of from about 100 to about 130;

K_5 is a value in the range of from about 3 to about 10;

K_6 is a value in the range of from about 30 to about 50;

K_7 is a value in the range of from about 5 to about 20;

R31 is the value of LANDSAT TM band 3 divided by LANDSAT TM band 1, after subtraction for atmospheric haze separately in each band;

R41 is the value of LANDSAT TM band 4 divided by LANDSAT TM band 1, after subtraction for atmospheric haze separately in each band;

R43 is the value of LANDSAT TM band 4 divided by LANDSAT TM band 3, after subtraction for atmospheric haze separately in each band;

R53 is the value of LANDSAT TM band 5 divided by LANDSAT TM band 3, after subtraction for atmospheric haze separately in each band;

R73 is the value of LANDSAT TM band 7 divided by LANDSAT TM band 3, after subtraction for atmospheric haze separately in each band; and

R74 is the value of LANDSAT TM band 7 divided by LANDSAT TM band 4, after subtraction for atmospheric haze separately in each band.

4. A method according to claim 6 wherein:

X is the amount of phycocyanin algae expressed in micrograms per liter;

K_1 is a value in the range of from about 45 to about 50;

K_2 is a value in the range of from about 7 to about 11;

K_3 is a value in the range of from about 25 to about 35;

K_4 is a value in the range of from about 110 to about 120;

K_5 is a value in the range of from about 5 to about 8;

K_6 is a value in the range of from about 35 to about 45; and

K_7 is a value in the range of from about 10 to about 15;

5.   A method according to claim 6 wherein:

X is the amount of phycocyanin algae expressed in micrograms per liter;

K_1 is a value in the range of from about 46 to about 48;

K_2 is a value in the range of from about 8 to about 10;

K_3 is a value in the range of from about 27 to about 30;

K_4 is a value in the range of from about 115 to about 120;

K_5 is a value in the range of from about 6 to about 8;

K_6 is a value in the range of from about 38 to about 43; and

K_7 is a value in the range of from about 13 to about 15;

6.   A method according to claim 1 wherein the calculated value of phycocyanin correlates to the actual measured amount of said phycocyanin in said water by a correlation value in excess of 60%.

7.   A method according to claim 1 wherein the calculated value of phycocyanin correlates to the actual measured amount of said phycocyanin in said water by a correlation value in excess of 70%.

8.	A method according to claim 5 wherein the calculated value of X

correlates to the actual measured amount of said phycocyanin in said water by a

correlation value in excess of 60%.

9.	A method according to claim 5 wherein the calculated value of X

correlates to the actual measured amount of said phycocyanin in said water by a

correlation value in excess of 70%.

10.	A method according to claim 1 additionally comprising the step of

transmitting data relating to the approximate amount of said phycocyanin to a site

remote from the site where said measurement takes place.

11.	A method according to claim 5 additionally comprising the step of

transmitting data relating to the approximate amount of said phycocyanin in said

water to a site remote from the site where said measurement takes place.

12.	A method of determining the presence of phycocyanin algae or bacteria in

water from light reflected therefrom, said method comprising the steps of:

(a) obtaining a measurement of reflected light from said water, said

measurement comprising a measurement of the respective amount of light in at

least four frequencies comprising, respectively: (i) LANDSAT TM band 1, (ii)

LANDSAT TM band 3, LANDSAT TM band 5, and (iv) LANDSAT TM band 7;

and (b) relating the approximate amount of said phycocyanin in said water to said

respective amounts of light by applying an algorithm relating said respective

amounts of light in said at least five frequency ranges to the amount of

phycocyanin algae in said water, wherein said algorithm is any algorithm

selected from the group consisting of: $X \approx K_1 - K_2 \times (R31) + K_3 \times (R41) - K_4 \times$

$(R43) - K_5 \times (R53) + K_6 \times (R73) - K_7 \times (R74)$ and equivalents wherein:

X is the approximate amount of phycocyanin algae expressed in micrograms per

liter;

K_1 is a value of about 48;

K_2 is a value of about 9;

K_3 is a value of about 30;

K_4 is a value of about 118;

K_5 is a value of about 7;

K_6 is a value of about 42;

K_7 is a value of about 15;

R31 is the value of LANDSAT TM band 3 divided by LANDSAT TM band 1, after

subtraction for atmospheric haze separately in each band;

R41 is the value of LANDSAT TM band 4 divided by LANDSAT TM band 1, after

subtraction for atmospheric haze separately in each band;

R43 is the value of LANDSAT TM band 4 divided by LANDSAT TM band 3, after

subtraction for atmospheric haze separately in each band;

R53 is the value of LANDSAT TM band 5 divided by LANDSAT TM band 3, after

subtraction for atmospheric haze separately in each band;

R73 is the value of LANDSAT TM band 7 divided by LANDSAT TM band 3, after

subtraction for atmospheric haze separately in each band; and

R74 is the value of LANDSAT TM band 7 divided by LANDSAT TM band 4, after

subtraction for atmospheric haze separately in each band.

13. A method according to claim 1 additionally comprising the step of transmitting data relating to the approximate amount of said phycocyanin in said water to a site remote from the site where said measurement takes place.

14. A method according to claim 12 additionally comprising the step of generating a report of said approximate amount of said phycocyanin in said water.

15. A method according to claim 12 additionally comprising the step of transmitting data relating to the approximate amount of said phycocyanin in said water to a site remote from the site where said measurement takes place.

Measurement Method followed by Transmission to Remote Processing Site

16. A method of determining the presence of phycocyanin algae in water from light reflected therefrom, said method comprising the steps of:

(a) obtaining a measurement of reflected light from said water, said measurement comprising a measurement of the respective amount of light in at least five frequency ranges: (i) from about 0.45 µm to about 0.52 µm; (ii) from about 0.63 µm to about 0.69 µm; (iii) from about 0.76 µm to about 0.90 µm; (iv) from about 1.55 µm to about 1.75 µm; and (v) from about 2.08 µm to about 2.35 µm;

transmitting data relating to said measurement to a site remote from said measurement device; and relating the approximate amount of said phycocyanin expressed in micrograms per liter in said water to said respective amounts of light at said remote site by applying an algorithm relating said respective amounts of light in said at least five frequency ranges to the amount of

phycocyanin algae in said water.

17. A method according to claim 16 additionally comprising the step of generating a report of said approximate amount of said phycocyanin in said water.

Apparatus for Detecting Phycocyanin algae or bacteria from Reflected Light

Self-contained Measurement/Processor Apparatus

18. An apparatus for determining the presence of phycocyanin algae or bacteria in water from light reflected therefrom, said device comprising:

(a)   a measurement device adapted to measure reflected light from said water, said measurement comprising a measurement of the respective amount of light in at least five frequency ranges: (i) from about 0.45 μm to about 0.52 μm; (ii) from about 0.63 μm to about 0.69 μm; (iii) from about 0.76 μm to about 0.90 μm; (iv) from about 1.55 μm to about 1.75 μm; and (v) from about 2.08 μm to about 2.35 μm; and

(b)   a processor capable of relating the approximate amount of said phycocyanin in said water to said respective amounts of light by applying an algorithm relating said respective amounts of light in said at least five frequency ranges to the amount of phycocyanin algae or bacteria in said water.

19. Apparatus according to claim 31 wherein said measurement of the amount of light in said at least five frequency ranges comprises the measurement, respectively, of: (i) LANDSAT TM band 1, (ii) LANDSAT TM band 3, (iii) LANDSAT TM band 4 (iv) LANDSAT TM band 5, and (v) LANDSAT TM band 7.

20. An apparatus according to claim 34 wherein said algorithm is any algorithm selected from the group consisting of: $X \approx K_1 - K_2 \times (R31) + K_3 \times (R41) - K_4 \times (R43) - K_5 \times (R53) + K_6 \times (R73) - K_7 \times (R74)$ and equivalents wherein:

X is the approximate amount of phycocyanin algae or bacteria expressed in micrograms per liter;

K_1 is a value in the range of from about 30 to about 60;

K_2 is a value in the range of from about 5 to about 15;

K_3 is a value in the range of from about 20 to about 35;

K_4 is a value in the range of from about 100 to about 130;

K_5 is a value in the range of from about 3 to about 10;

K_6 is a value in the range of from about 30 to about 50;

K_7 is a value in the range of from about 5 to about 20;

R31 is the value of LANDSAT TM band 3 divided by LANDSAT TM band 1, after subtraction for atmospheric haze separately in each band;

R41 is the value of LANDSAT TM band 4 divided by LANDSAT TM band 1, after subtraction for atmospheric haze separately in each band;

R43 is the value of LANDSAT TM band 4 divided by LANDSAT TM band 3, after subtraction for atmospheric haze separately in each band;

R53 is the value of LANDSAT TM band 5 divided by LANDSAT TM band 3, after subtraction for atmospheric haze separately in each band;

R73 is the value of LANDSAT TM band 7 divided by LANDSAT TM band 3, after subtraction for atmospheric haze separately in each band; and

R74 is the value of LANDSAT TM band 7 divided by LANDSAT TM band 4, after subtraction for atmospheric haze separately in each band.

21. An apparatus according to claim 35 wherein:

X is the amount of phycocyanin algae or bacteria expressed in micrograms per liter;

K_1 is a value in the range of from about 45 to about 50;

K_2 is a value in the range of from about 7 to about 11;

K_3 is a value in the range of from about 25 to about 35;

K_4 is a value in the range of from about 110 to about 120;

K_5 is a value in the range of from about 5 to about 8;

K_6 is a value in the range of from about 35 to about 45; and

K_7 is a value in the range of from about 10 to about 15.

22. An apparatus according to claim 35 wherein:

X is the amount of phycocyanin algae or bacteria expressed in micrograms per liter;

K_1 is a value in the range of from about 46 to about 48;

K_2 is a value in the range of from about 8 to about 10;

K_3 is a value in the range of from about 27 to about 30;

K_4 is a value in the range of from about 115 to about 120;

K_5 is a value in the range of from about 6 to about 8;

K_6 is a value in the range of from about 38 to about 43; and

K_7 is a value in the range of from about 13 to about 15.

23.   An apparatus according to claim 31 additionally comprising a report generator adapted to generate a report of said approximate amount of said phycocyanin in said water.

24.   An apparatus according to claim 31 additionally comprising a transmitter adapted to transmit data relating to the approximate amount of said phycocyanin in said water from said processor to a site remote from the site where said measurement takes place.   '

25.   An apparatus according to claim 31 wherein said measurement device is a camera.

26.   An apparatus according to claim 31 wherein said processor is a microprocessor having programming instructions for applying said algorithm.

27.   An apparatus according to claim 31 wherein said algorithm comprises a linear relationship between said approximate amount of said phycocyanin in said water and sum of (a) the ratio of said first frequency to said second frequency and (b) the ratio of said second frequency to said third frequency.

Specific Devices based upon selected Claims

28. A buoy comprising an apparatus according to claim 31.

29. A buoy comprising an apparatus according to claim 35.

30. A hand-held device comprising an apparatus according to claim 31.

31. A hand-held device comprising an apparatus according to claim 35.

32. A hand-held device comprising an apparatus according to claim 37.

More Algorithm-specific Self-contained Measurement/Processor Apparatus

33. An apparatus for determining the presence of phycocyanin algae or bacteria in water from light reflected therefrom, said device comprising:

(a) a measurement device adapted to measure reflected light from said water, said measurement comprising a measurement of the respective amount of light in at least four frequencies comprising, respectively: (i) LANDSAT TM band 1, (ii) LANDSAT TM band 3, (iii) LANDSAT TM band 4, (iv) LANDSAT TM band 5, and (v) LANDSAT TM band 7; and

(b) a processor capable of relating the approximate amount of said phycocyanin in said water to said respective amounts of light by applying an algorithm relating said respective amounts of light in said at least five frequency ranges to the amount of phycocyanin algae or bacteria in said water, wherein said algorithm is any algorithm selected from the group consisting of: $X \approx K_1 - K_2 \times (R31) + K_3 \times (R41) - K_4 \times (R43) - K_5 \times (R53) + K_6 \times (R73) - K_7 \times (R74)$ and equivalents wherein:

X is the approximate amount of phycocyanin algae or bacteria expressed in micrograms per liter;

K_1 is a value in the range of from about 30 to about 60;

K_2 is a value in the range of from about 5 to about 15;

K_3 is a value in the range of from about 20 to about 35;

K_4 is a value in the range of from about 100 to about 130;

K_5 is a value in the range of from about 3 to about 10;

K_6 is a value in the range of from about 30 to about 50;

K_7 is a value in the range of from about 5 to about 20;

R31 is the value of LANDSAT TM band 3 divided by LANDSAT TM band 1, after subtraction for atmospheric haze separately in each band;

R41 is the value of LANDSAT TM band 4 divided by LANDSAT TM band 1, after subtraction for atmospheric haze separately in each band;

R43 is the value of LANDSAT TM band 4 divided by LANDSAT TM band 3, after subtraction for atmospheric haze separately in each band;

R53 is the value of LANDSAT TM band 5 divided by LANDSAT TM band 3, after subtraction for atmospheric haze separately in each band;

R73 is the value of LANDSAT TM band 7 divided by LANDSAT TM band 3, after subtraction for atmospheric haze separately in each band; and

R74 is the value of LANDSAT TM band 7 divided by LANDSAT TM band 4, after subtraction for atmospheric haze separately in each band.

34.   An apparatus according to claim 31 additionally comprising a report generator adapted to generate a report of said approximate amount of said phycocyanin in said water.

35.   An apparatus according to claim 31 additionally comprising a transmitter adapted to transmit data relating to the approximate amount of said phycocyanin in said water from said processor to a site remote from the site where said measurement takes place.

<u>System Using Transmission of Light Measurement Data to Processor</u>

36.   A system for determining the presence of phycocyanin algae or bacteria in water from light reflected therefrom, said device comprising:

(a)   a measurement device adapted to measure reflected light from said water, said measurement comprising a measurement of the respective amount of light in at least five frequency ranges: (i) from about 0.45 µm to about 0.52 µm; (ii) from about 0.63 µm to about 0.69 µm; (iii) from about 0.76 µm to about 0.90 µm; (iv) from about 1.55 µm to about 1.75 µm; and (v) from about 2.08 µm to about 2.35 µm; and

(b)   a processor at said remote site and capable of relating the approximate amount of said phycocyanin in said water to said respective amounts of light by applying an algorithm relating said respective amounts of light in said at least five frequency ranges to the amount of phycocyanin algae or bacteria in said water.

37.   A method of developing an apparatus for determining the presence of phycocyanin algae or bacteria in water from light reflected therefrom, said device comprising:

(a)   obtaining a measurement of reflected light from said water, said measurement comprising a measurement of the respective amount of light of at least two frequencies;

(b)   developing an algorithm relating said respective amounts of light in said at least two frequencies to the amount of phycocyanin algae or bacteria in said water through linear regression analysis;

(c)   producing a processor capable of relating the approximate amount of said phycocyanin in said water to said respective amounts of light by applying an algorithm relating said respective amounts of light in said at least five frequency ranges to the amount of phycocyanin algae or bacteria in said water;

(d)   providing a measurement device adapted to measure reflected light from said water and adapted to provide data relating to said measurement to said processor.